



Infrared Space Astronomy in Germany

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Bonn, Germany**

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German Space Science Program

Programmatic Focus

- **Study origins and evolution of our solar system and the Earth by exploring Mars, Mercury and comets**
- **Study life cycles of stars, evolution of galaxies, and structure of the early universe**
- **Search for extra-solar planets**
- **Search for extra-terrestrial life within the solar system (e.g. Mars, Europa)**
- **Examine laws of fundamental physics, detect gravitational waves**



German Space Science Program

Competence

- **Strong scientific community in Max-Planck-Institutes, universities, research institutes, DLR**
- **Active in most fields of astronomy, solar system research, fundamental physics, astro-/exobiology**
- **Special competence in selected areas like x-ray astronomy, IR astronomy, plasma physics, planetary/cometary exploration, gravitational waves**
- **Technological competence for forefront instrumentation both in science institutes and in industry**
- **System competence for science missions in industry**



German Space Science Program

Program Elements (1)

ESA Science Program HORIZON 2000+

- Long term stable program for Europe
- Defined by the science community
- Germany largest share holder (25%)
- Strong German participation in definition and execution of science missions
- Substantial contributions to science instrumentation
- Large share in data evaluation



German Space Science Program

Program Elements (2)

International cooperation

- Complementary to ESA science program
- Participation to assure continuous flow of new data in all fields of space science
- Worldwide cooperation; main partners USA, France, Russia, Sweden, Norway, Denmark, Japan
- Role in cooperation ranges between small CoI-contributions, full PI-experiments, significant hardware contributions to missions (e.g. GALILEO, SOFIA), leadership in projects (e.g. ROSAT, ASTRO-SPAS)
- Potential for international contributions to national projects (e.g. in small missions)



German Space Science Program

Missions

Participation in all ESA science missions, e.g.

In orbit: Ulysses, Cassini/Huygens, SOHO, XMM, CLUSTER II

**Under development: INTEGRAL, ROSETTA, MARS-EXPRESS,
Herschel/Planck**

In preparation: BepiColombo, GAIA, NGST, LISA, Solar Orbiter

International participation (substantial contributions)

In Orbit: GALILEO, CHANDRA

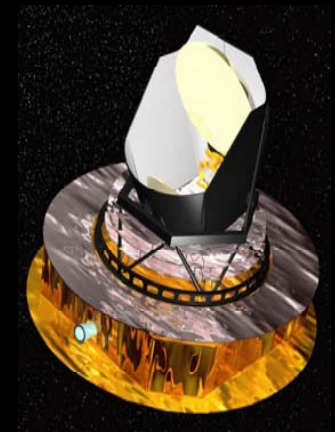
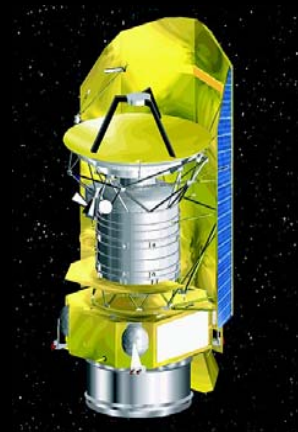
**Under development: SOFIA, MARS-2003 Rovers, AMS, NetLander, STEREO,
GLAST**

Small mission opportunities



Overview: Infrared/mm Airborne and Space Observatories with German Participation

ISO	SOFIA	Herschel	Planck
1995	2004	2007	2007
0.6 m	2.7 m	3.5 m	1.5 m
1.5 yrs	20 yrs	3 yrs	1.5 yrs
ESA/JPN/USA	USA/Germany	ESA	ESA





ISO: Infrared Space Observatory



Dimensions (HxWxD):	5.3 x 3.6 x 2.8 m
Mirror Size:	0.6 m
Weight:	2.4 t
Launcher:	Ariane 44P
Mission life:	Nov 17, 1995 - May 16, 1998
Orbit:	highly elliptical 1.000 - 70.500 km
Wavelength coverage:	2.5 to 240 μm
Instruments on board:	ISOCAM, ISOPHOT, SWS, LWS
Temperature:	- 269° C (all instruments)



German Contributions to ISO Instrumentation

- **ISOPHOT (2.5 - 240 μm) :**



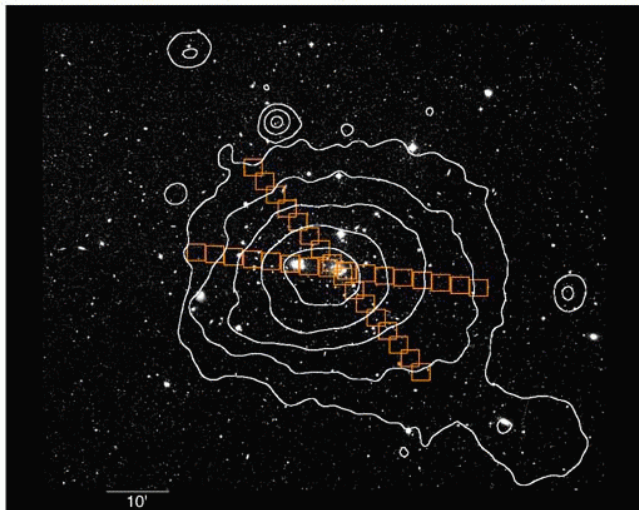
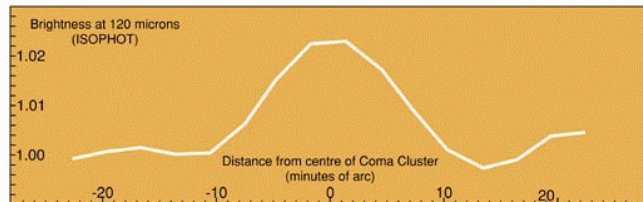
 - Max Planck Institut für Astronomie, Heidelberg (PI Institute)
 - Battelle Europe, Frankfurt am Main
 - Carl Zeiss, Oberkochen
 - Deutsche Aerospace (Dornier), Friedrichshafen (now : Astrium)
 - Freie Universität Berlin
 - Max Planck Institut für Kernphysik, Heidelberg
 - Max Planck Institut für Radioastronomie, Bonn
- **LWS (45 - 196.8 μm):**
 - Battelle Europe, Frankfurt am Main
- **SWS (2.4 - 45 μm):**
 - Battelle Europe, Frankfurt am Main
 - Max Planck Institut für Extraterrestrische Physik, Garching



ISO Science Highlights

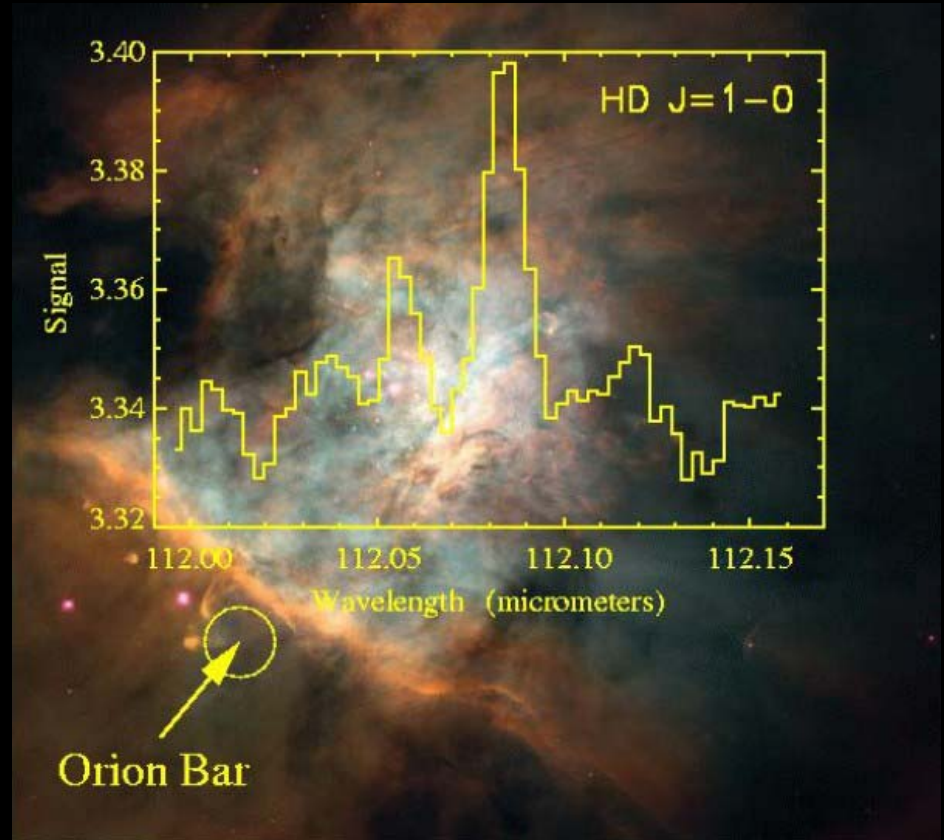


INTERGALACTIC DUST IN THE COMA CLUSTER



Coma Cluster with X-ray contours (white) and ISO scanlines (orange)

Credits: ISO graph and scan lines: ESA/ISO, M. Stickel, D. Lemke & ISOPHOT Team
Visible-light image: STScI Digitized Sky Survey
X-ray contours: ROSAT Data Archive & S. White, A. Vikhlinin

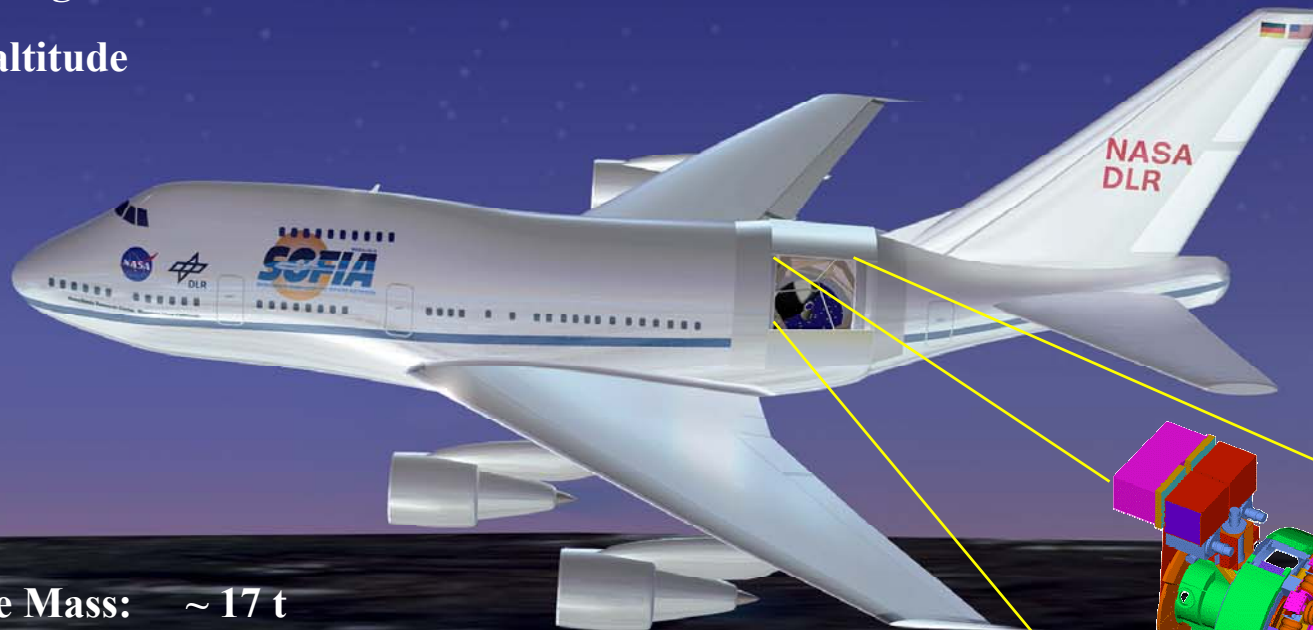


Deuterium: fossile element of Big Bang

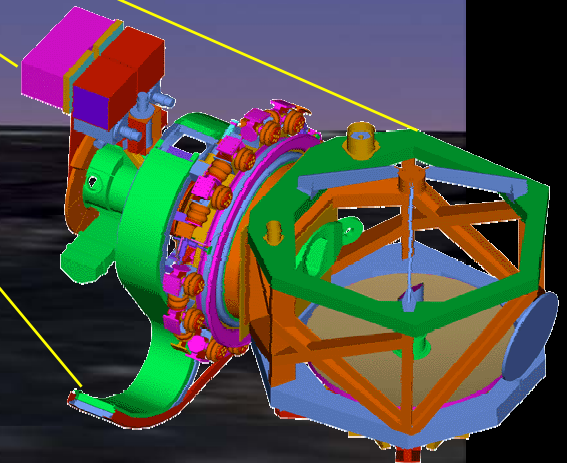


Stratospheric Observatory for Infrared Astronomy (SOFIA)

~160 flights/yr
~7 hours/night
~14 km altitude

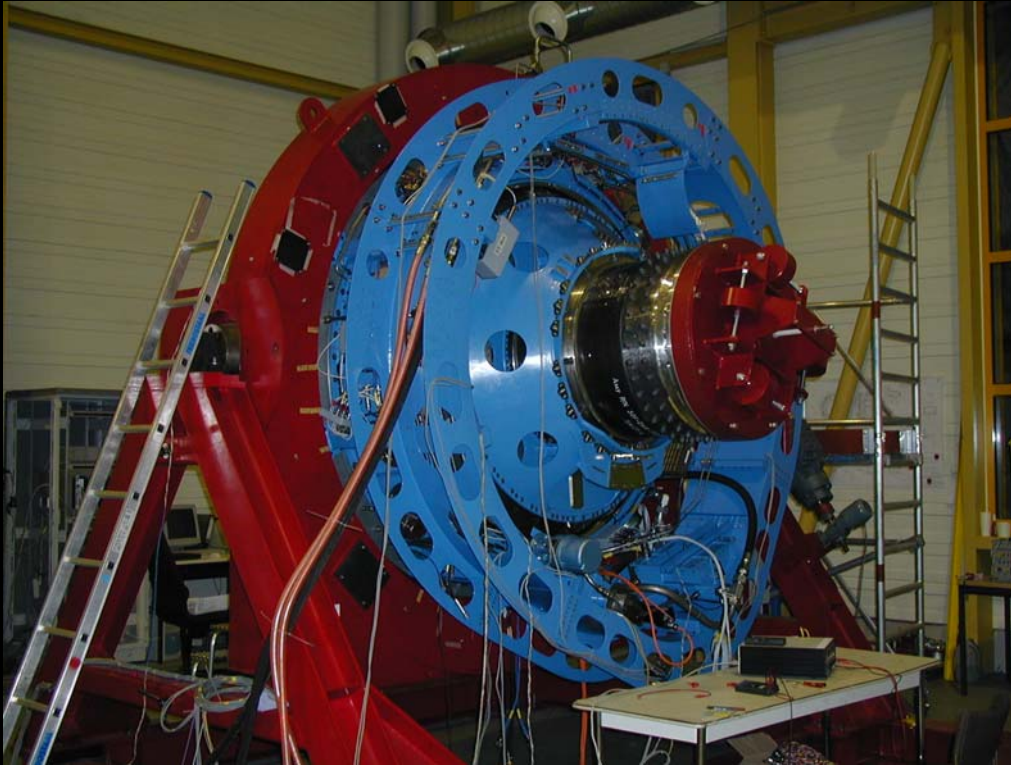


Telescope Mass: ~ 17 t
Spectral Range: 0.3 - 1.600 μm
Pointing Stability: 0.2" rms

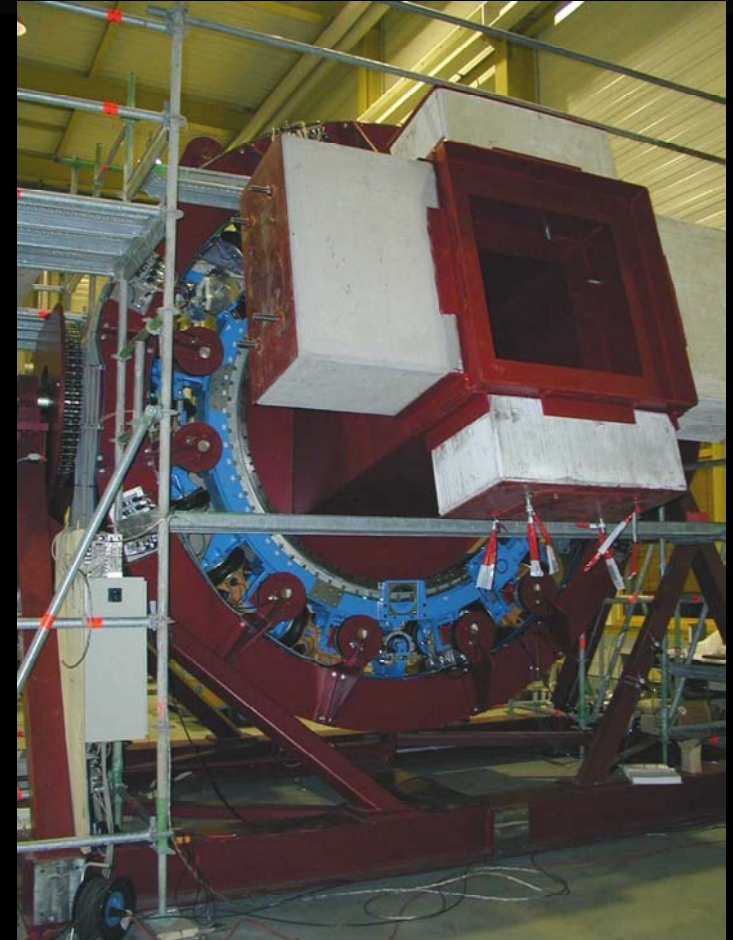




SOFIA Hardware Highlights (1)



**Suspension Isolation System with Rotation Drive
Assembly, Nasmyth Tube and Cable Load Alleviator**



**Vibration Isolation System with
Telescope Dummy in Dummy Bulkhead**



SOFIA Hardware Highlights (2)



**Metering Structure with
Primary Mirror Cell**



SOFIA's Heart: Primary Mirror at SAGEM in Paris

Diameter: 2.7 m

PM f-ratio: 1.28 m

Mass: 888 kg



German Contributions to SOFIA Instrumentation (1)

- **GREAT (German Receiver for Astronomy at THz Frequencies)**

Modular dual-channel heterodyne instrument for high-resolution spectroscopy ($\nu/\Delta\nu \sim 10^{6-8}$):

- **low-frequency band:** 1.6-1.9 THz (University of Cologne)
- **mid-frequency band:** 2.4-2.7 THz (MPIfR, Bonn)
- **high-frequency band:** ca. 4.7 THz (DLR, Berlin)

with two possible backends:

- **mid-resolution Array Acousto-Optical Spectrometer (4x1 GHz bandwidth, $\Delta\nu=1$ MHz)**
(University of Cologne)
- **high-resolution Chirp-Transform-Spectrometer (CTS) with 180 MHz bandwidth,**
 $\Delta\nu=45$ kHz (MPAe, Lindau)

Detectors will employ superconducting HEB mixers or SIS junctions



German Contributions to SOFIA Instrumentation (2)

- FIFI LS (Far-Infrared Fied-Imaging Line Spectrometer)**

Simultaneous 3D imaging - 2D spatially and 1D spectrally in two channels:

Wavelength:	42-110 μm	110-210 μm
Detector Type:	Ge : Ga	stressed Ge : Ga
Spatial (Spectral) Pixels:	5 x 5 (16)	5 x 5 (16)
Field of View:	30" x 30"	60" x 60"
Velocity Resolution:	150-300 km/s	150-300 km/s

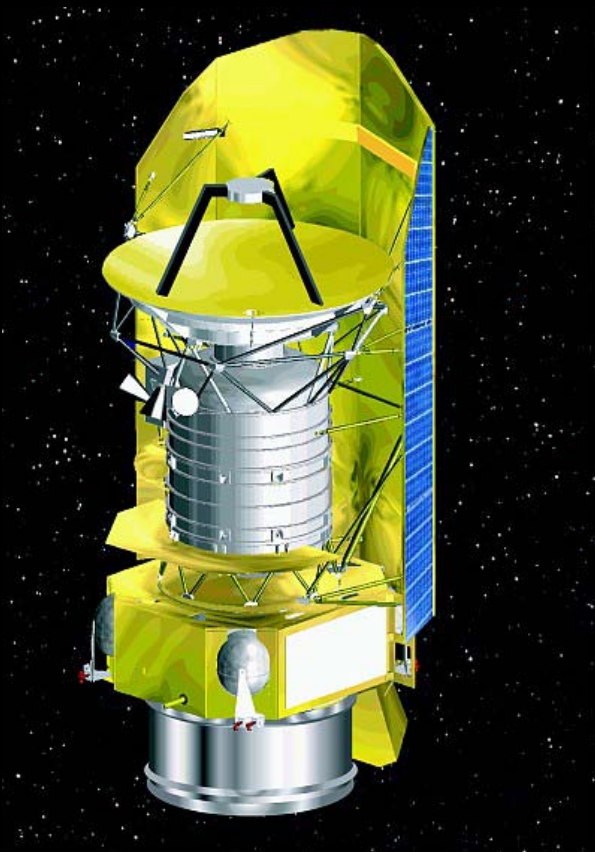
Collaborators: MPE, Garching; University of Jena; LBL, Berkeley

- Possible future instrument: SPICA (Spectral-Photometric Infrared Camera)**

Three imaging Detector Arrays (Si-BIB, Ge : Ga and stressed Ge : Ga) for spectral range from 20 to 220 μm



Future Infrared und Submm Satellites: Herschel Space Observatory (HSO)



Length:	9 m
Telescope:	3.5 m Ritchey-Chrétien at 80 K
Launch Mass:	3.25 t
Launch Vehicle:	Ariane 5
Mission Duration:	> 3 yrs
Key Science Objectives:	<ul style="list-style-type: none">• Formation and Evolution of Galaxies in the Early Universe• Physics of ISM, Star Formation and Stellar Evolution• study cometary, planetary, and satellite atmospheres



Herschel Science Instruments (1)

Three cryogenically cooled instruments with wavelength coverage from 60 - 670 μm

- **HIFI (Heterodyne Instrument for the Far-IR)**
 - consisting of local oscillators, control units and spectrometers, and the HIFI focal plane unit
 - continuous frequency coverage from 480 to 1250 GHz and a high frequency channel at 1410 - 1910 GHz
 - receiver optimised for detection of broad weak line emission (e.g. from distant galaxies) and for high-speed line surveys of ISM

German Institutes participating in the Hardware:

Uni of Cologne: AOS with bw 4 GHz, mixer unit incl. detector for band II (640-800 GHz)

MPIfR, Bonn: Local oscillator units, multiplier chains for band I to IV

MPAE, Lindau: Space qualified electronics & corresponding intermediate frequency units



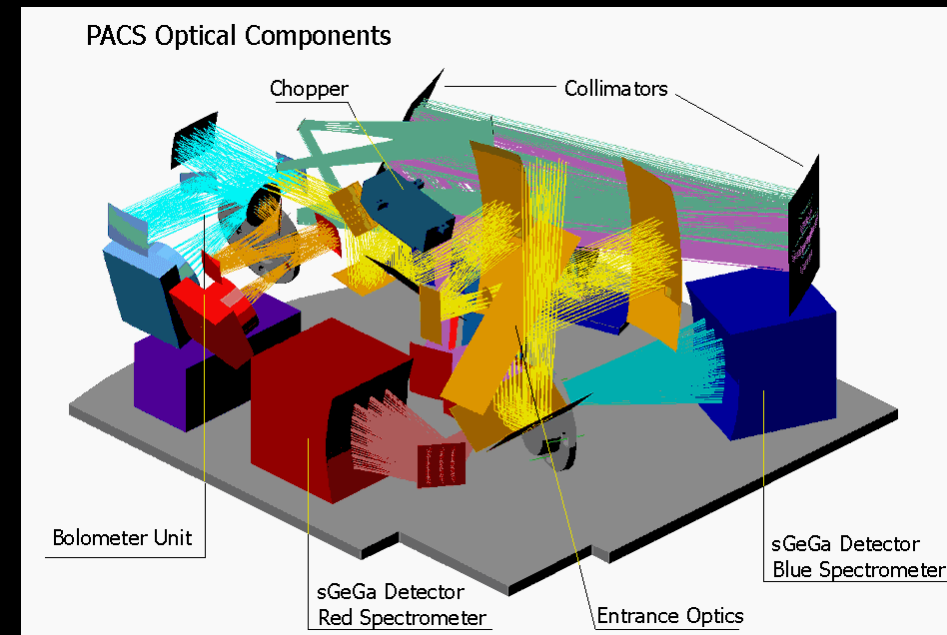
Herschel Science Instruments (2)

- PACS (Photodetector Array Camera & Spectrometer)**

employs two Ge : Ga photoconductor arrays
(stressed/unstressed) and two bolometer arrays

Imaging photometry

- Two bands simultaneously: 60 - 90 μm or 130 - 210 μm and 130 - 210 μm with dichroic beam splitter
- Two filled bolometer arrays (32 x 16 and 64 x 32 pixels)





Herschel Science Instruments (3)

- PACS (cont'd)

Integral field line spectroscopy

- wavelength range 57 - 210 μm
- optical image slicer (rearrange 2D field of view along 1D slit)
- long slit grating spectrograph ($R \sim 1500$) for light dispersion
- dispersed slit image projected on Ge : Ga photoconductor array (stressed/unstressed)

PACS Consortium led by MPE, Garching with participation of University of Jena, MIPA, Heidelberg and institutes from Austria, Belgium, France, Italy and Spain

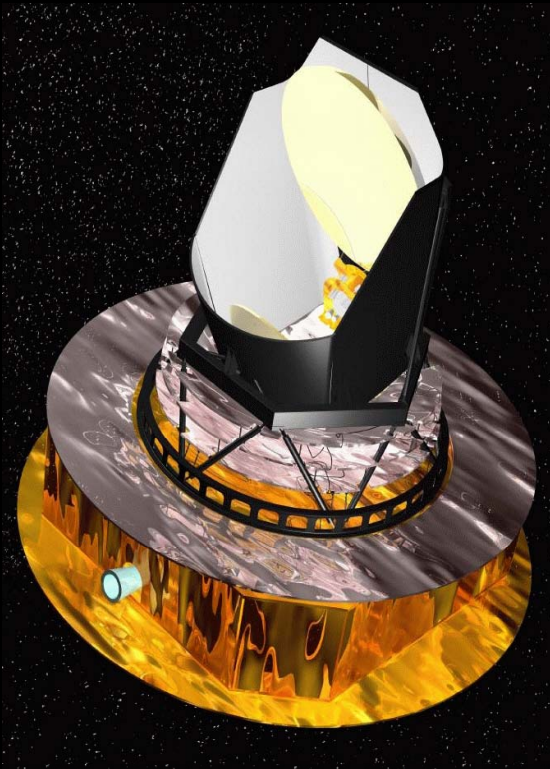
- SPIRE (Spectral and Photometric Imaging Receiver)

(European consortium w/o D participation led by UK)



Planck

Third Medium-Sized Mission (M3) of ESA's Horizon 2000+ Scientific Program



Length:	3.8 m
Telescope:	1.5 m Gregorian Reflector
Launch Vehicle:	Ariane 5
Mission Duration:	1.5 yrs
Science Objectives:	Measuring of temperature anisotropies in the Cosmic Microwave Background (CMB) with angular resolution $\sim 10'$

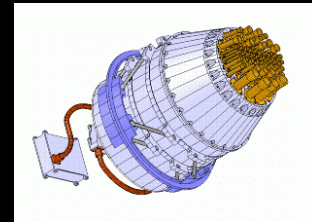


Planck Science Instruments

- **HFI High Frequency Instrument**

48 bolometric detectors, placed in focal plane of Planck telescope to image sky in six frequency channels between 100 and 857 GHz at 0.1 K

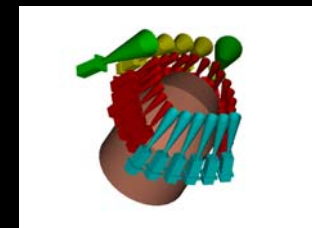
Consortium of about 20 European and US institutes w/o D



- **LFI Low Frequency Instrument**

56 tuned radio receivers, placed in focal plane of Planck telescope to image sky in four frequency channels between 30 and 100 GHz at 20 K

Consortium of about 20 European and US institutes w/o D



German Contribution to Planck Program by MPA, Garching:

Part of IDIS (Integrated Data and Information System); preparation of final data products for release; management and coordination of data reduction software



Herschel & Planck

Launch on Ariane 5

Separate after insertion in transfer trajectory

Orbit: Around Lagrangian Point L2 at

1.5 Mio km distance from Earth

Herschel → wide orbit

Planck → tight orbit

Ground contact 2 hrs/day

Autonomous Operations

